The impact of changes in parameterizations of surface drag and vertical diffusion on the large scale circulation and boundary layer wind turning in CAM5

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Investigating the role of surface friction
The Community Atmosphere Model (CAM5.3)

How is the boundary layer and the general circulation affected by added drag (Turbulent Mountain Stress, TMS) at the surface?

Do surface drag and turbulent diffusion affect the general circulation in a similar way?

Wind turning over the PBL is important for interaction with the large scale

Overall goal is to describe the local boundary-layer turbulence and the general circulation well
Subgrid-scale orographic drag

Sub-grid scale momentum transfer are done by several parameterizations

Subgrid-scale orographic drag is parameterized as an additional surface stress (TMS)

The size of the TMS is dependent on the stability and the variance of orography in a gridbox

The PBL is parameterized using a diagnostic TKE scheme (Bretherton and Park, 2009)
Changing turbulent diffusion

Default CAM5 (CONTROL)
No turbulence when Ri > 0.19

CAM5 with enhanced diffusion in stable conditions (Longtail)
More turbulence in stable conditions (Lindvall et al. 2013; 2014)
Large differences in the annual mean magnitude of the surface stress

Without subgrid scale turbulent orographic drag (\textit{NoTMS})

Higher diffusivity in stably stratified conditions + no turbulent orographic drag (\textit{LONGTAIL})
Near surface wind field

Lindvall et al, 2015

CONTROL

NoTMS – CONTROL

LONGTAIL – CONTROL

LONGTAIL PBL – CONTROL

Lindvall et al, 2015
Arctic annual mean sea level pressure

ERA-INTERIM

a)

CONTROL

b)

NoTMS – CONTROL
c)

LONGTAIL – CONTROL
d)

LONGTAIL PBL – CONTROL
e)
500 hPa streamfunction
Zonal anomaly
Blocking frequencies in CESM
Different sub-grid scale parameterisations of the surface drag

All model versions have too few blockings, specially for the Euro-Atlantic sector.
No version captures the Atlantic blockings in winter

Control is closest to observations

Blocking frequencies in CESM
Different sub-grid scale parameterisations of the surface drag

Lindvall et al, 2015
Tower data combined with sounding information

ARM Southern Great Plain site

Radiosondes are released four times daily
Use a RI based PBL height combined with surface stress observations
Density scatter plots, as well as individual PDFs, of wind direction (°) and temperature (°C) just above the PBL

(Lindvall and Svensson 2015)
The TMS in the CONTROL run gives too large wind turning over the boundary layer.

Longtail has the smallest wind turning.

No TMS and PBLH Longtail are very close to observations.
Boundary layer wind turning

SGP

Stably stratified

Unstable

Wind turning between surface and PBLH [°]

Unstable [%]
CTRL: 36
NoTMS: 38
Longtail: 35
PBLH Longtail: 37
OBS: 41

Weakly stable [%]
CTRL: 15
NoTMS: 8.3
Longtail: 6.6
PBLH Longtail: 8
OBS: 22

Stable [%]
CTRL: 49
NoTMS: 54
Longtail: 59
PBLH Longtail: 55
OBS: 37
Boundary layer wind turning
Sodankylä

**Stably stratified**

**Unstable**

Unstable [%]
- OBS Sod.: 56
- CTRL: 39
- NoTMS: 38
- Longtail: 35
- PBLH Longtail: 36

Weakly stable [%]
- CTRL: 15
- NoTMS: 8.3
- Longtail: 6.6
- OBS: 22

Stable [%]
- CTRL: 49
- NoTMS: 54
- Longtail: 59
- OBS: 38

Wind turning between surface and PBLH [°]

PBLH: PBL Height
PBL cross-isobaric flow

All simulations have more cross-isobaric flow than the observations at the Southern Great Plains site.

At Sodankylä the CONTROL and Longtail have too much, the other two compares well with observations.
Summary

Comparing the control simulation with experiments without turbulent orographic drag and with more turbulent diffusivity (longtail), we conclude:

• The orographic surface drag (TMS) has a substantial impact on both the boundary layer (wind turning over the PBL) and the general circulation (blocking frequency, stream functions, surface pressure)

• Increasing the turbulent diffusivity has not the same effect as the turbulent orographic surface drag in CAM5

• Only two sites are examined regarding the wind turning and cross-isobaric flow so far